International Civil Aviation Organization

THE FIFTH MEETING OF IONOSPHERIC STUDIES TASK FORCE (ISTF/5)

16 – 18 February 2015, Ishigaki, Japan

Agenda Item 3: Review of status of States' activities

DEVELOPMENT, TESTING AND VERIFICATION OFAATR GENERATION TOOLS AND RESULTS OF AATR ANALYSIS OVER INDIAN REGION

(Presented by Airports Authority of India, India)

SUMMARY

India's experience in the Ionospheric studies for GAGAN has been leveraged effectively for assisting ISTF. India has contributed mainly in terms of sharing of results, particularly with regard to Scintillations (Data from 23 stations out of total 37 nominated in the region). India also hosted the last Meeting i.e. 4th Meeting of ISTF at New Delhi from February 5-7, 2014.

AATR parameter identifies the regional irregularity and would be useful for data mining by all associated ISTF member states. India in collaboration with Japan and Australia was involved in *design, development and verification* of data analysis tools for gradient estimation (AATR). The working paper presents the process adopted by India for testing and verification of AATR (Along-Arc TEC Rate) generation tools developed independently by Japan and India and recommends ISTF to examine the methodology for testing and verification and the results of AATR tool for use in regional Ionospheric work.

1. Introduction

1.1 India's experience in the Ionospheric studies for GAGAN has been leveraged effectively for assisting ISTF. India has contributed mainly in terms of sharing of results, particularly with regard to Scintillations (Data from 23 stations out of total 37 nominated in the region). India also hosted the last Meeting i.e. 4th Meeting of ISTF at New Delhi from February 5-7, 2014.

1.2 India has provided valuable inputs to the task force. Some of them are:

- Longitudinal variations of Equatorial Ionization Anomaly;
- Characterization of TEC with respect to solar activity (solar flux) and latitude;
- Effect of scintillation on GNSS and GAGAN GEO integration;
- Space weather effects on performance of GAGAN etc.

1.3 India has been actively participating in all the meetings of ISTF and has presented 9 Working Papers and 6 Information Papers so far. India was also involved in all the 3 web-conferences held after 4th ISTF along with Japan (Chair of ISTF). **India proposed data mining technique based**

on confidence bound of polynomial fitting and provided the list of relevant dates for analysis of Ionospheric data. India also contributed in methodology for analysis and proposed data formats (SCINTEX and GTEX) etc.)

1.4 After ISTF 4 meeting in 2014, India, Japan and Australia were involved in *design, development and verification* of data analysis tools for gradient estimation- Along-Arc TEC Rate (AATR). *AATR parameter identifies the regional irregularity and would be useful for data mining* by all associated ISTF member states.

1.5 The working paper presents the process adopted by India for testing and verification of AATR (Along-Arc TEC Rate) generation tools developed independently by Japan and India. The results from the tools using the TEC data are also provided as appendix to the paper.

2. Discussion

2.1 The 1st Web-conference of ISTF held on 24 June 2014 decided to use Along- Arc TEC Rate (AATR) as one of the indicator for identifying nominal and disturbed ionospheric conditions at regional level. AATR is sensitive to both temporal and spatial gradients.

2.2 The software tool to generate AATR was developed independently by India in 'MATLAB' platform and ENRI, Japan in 'C' language. The output data format of the AATR tool is based on one of the formats suggested by Australia.

2.3 In order to adopt the AATR tools for data analysis and mining in ISTF, both the tools from Japan and India were tested and verified with same data source.

2.4 India developed the AATR tool 'findaatr' in MATLAB platform to generate the AATR parameter for GAGAN-TEC data which is in ISMRA format. The tool can be customized to handle data sampling interval of 15, 30 and 60 seconds from ISMRA data format. However 30 seconds sampling interval was finalized for ISTF purpose.

2.5 ENRI, Japan provided the 'C' source code of their AATR tool compiled in UNIX for ISMRA and RINEX data sources known as 'ismra2aatr' and 'rinex2aatr' respectively.

2.6 India successfully compiled the 'C' codes of ENRI's AATR tool in 'Cygwin' environment on Windows machines. Some issues, in this process, were reported to ENRI and duly rectified.

2.7 India generated the raw AATR data using their own MATLAB code 'findaatr' and compared the results with AATR generated from 'ismra2aatr' and 'rinex2aatr' tools. The ISMRA and RINEX data were obtained from same receiver for same day.

2.8 Figure 1 show the instantaneous AATR (left panel) and hourly RMS AATR (right panel) derived from the above mentioned three codes for same station –Khajuraho (Receiver ID-915) for 31st March 2012.

2.9 The raw instantaneous AATR shows very good agreement in outputs from C and MATLAB codes using ISMRA data. The amplitude of AATR from C code is relatively higher than that of MATLAB. The raw AATR from RINEX data shows similar nature but with less data points, probably due to filtration of cycle slip data.

2.10 The hourly RMS of AATR **also shows very good agreement between the three codes**. However, there is slight difference in amplitude of RMS AATR, especially between C and MATLAB codes using ISMRA data source.

2.11 Further comparison was carried out for all days of year 2012 using daily mean values of RMS AATR for the same station- Khajuraho as shown in Figure 2. It is clearly evident that both the AATRs are in sync with each other; however the amplitude of AATR from 'C' code is relatively higher than that of 'MATLAB'.

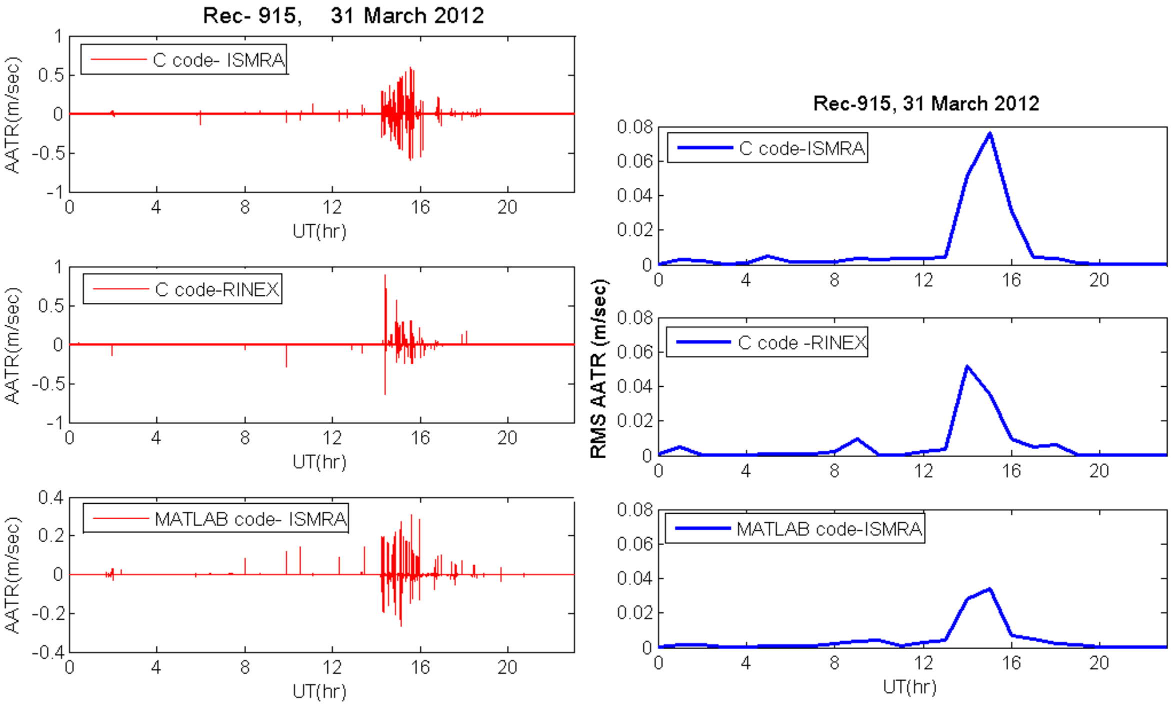

Figure 1: Comparison of raw instantaneous AATR (left) and hourly RMS AATR generated from three codes but with same data source in two different formats (ISMRA and RINEX).

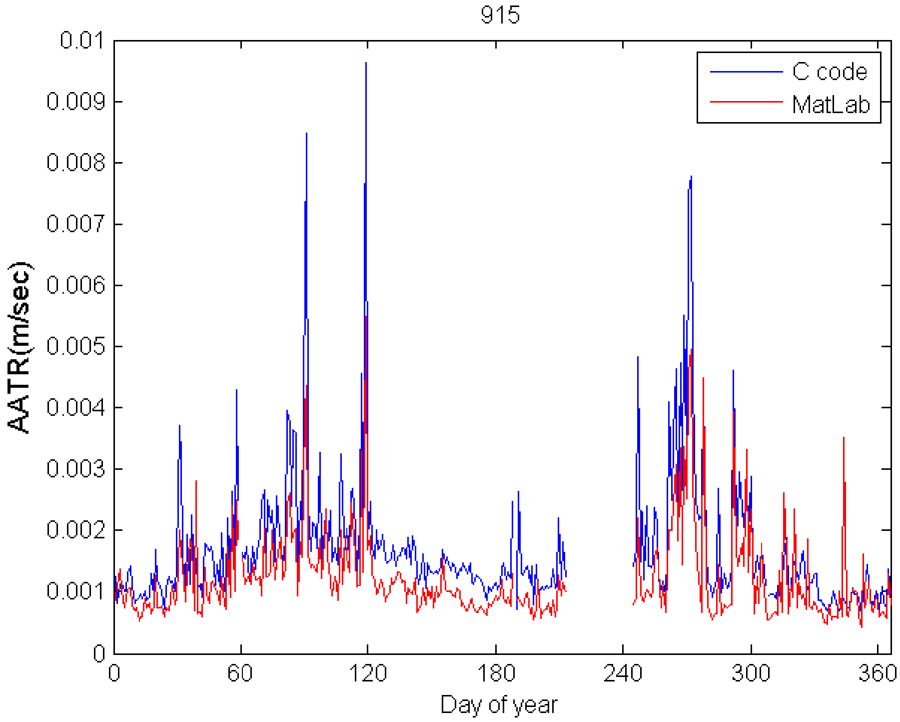

Figure 2: Comparison of daily mean of RMS AATR for ENRI's 'C' (blue line) and India's'MATLAB' (red line) codes for all days of year 2012 for the station Khajuraho (24.82° N, 79.92° E, Rec ID- 915).

3. Results of AATR Analysis over Indian region

3.1 Following the verification of tools, India has generated the AATR parameter for shared data of GAGAN-TEC network for the years- **2004, 2008 and 2012** representing the moderate, low and high solar activity periods. The shared data format is ISMRA.

3.2 The generation of AATR parameter and consequent analysis has been performed using both the AATR tools developed by India and Japan. However, the results presented here were derived from the tool provided by Japan as same tool is being used for AATR generation/analysis of the collected data in ISTF server hosted by Japan.

3.3 The instantaneous AATR values, sometimes, consists of spikes and surges due to satellite change over and/or other inherent data related issues, making it difficult to automatically distinguish between real and exaggerated (false) values and requires manual data verification as shown in Figure 3 (a).

3.4 The daily mean of hourly RMS of instantaneous AATR values for all visible satellites can be used to delineate the exaggerated values as shown in Figure 3 (b). The unusually high values of daily mean RMS AATR during January-February is obviously due to spikes as shown in Figure 3 (a).

3.5 Since the hourly RMS of AATR provides regional solution irrespective of any particular satellite/direction, the further analysis was carried out using RMS AATR only.

3.6 In order to identify Ionospheric worst case scenarios, the maximum values of RMS AATR for the years -2004, 2008 and 2012 were calculated separately for each receiver and are tabulated in Appendix A. Most of the worst days are from equinoctial months and some of them are even same for different receivers.

3.7 Since the worst case conditions are rare events, a more statistically significant parameter is 99.7th percentile of AATR, which is also tabulated in Appendix A. Figure 4 shows the variation of year wise 99.7th percentile AATR with geographic latitude. The low values of AATR (less than 0.005 m/sec) during 2008, a low solar activity period, are obvious. During high solar activity, like in 2012, most of the receivers have 99.7th percentile AATR above 0.02 m/sec. Moreover, large values of AATR are found to be in low latitude region followed by equatorial and then mid latitude region.

3.8 Further, the daily mean of RMS AATR for two stations- Shimla, near low- mid latitude region and Aizwal, near an anomaly crest region is calculated for each year of 2004, 2008 and 2012 as shown in Figure 5. The values at Aizwal are twice of the order of Shimla and exhibit semi-annual variations.

3.9 The manual verification of results is being carried out further to remove any discrepancies in the results.

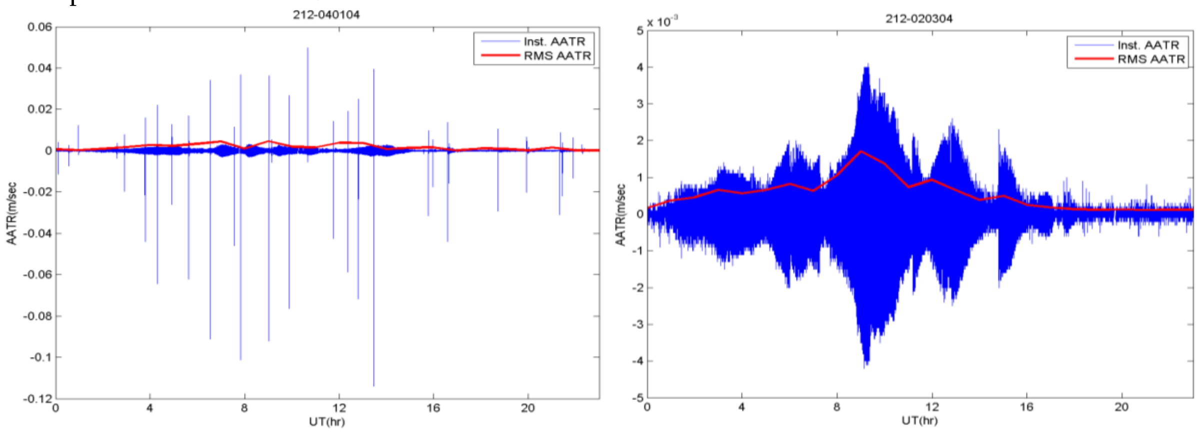

Figure 3(a): Instantaneous and RMS values of AATR for two different days for same receiver at New Delhi. Left side plot is for 4th January 2004 and right side plot is for 2nd March 2004.

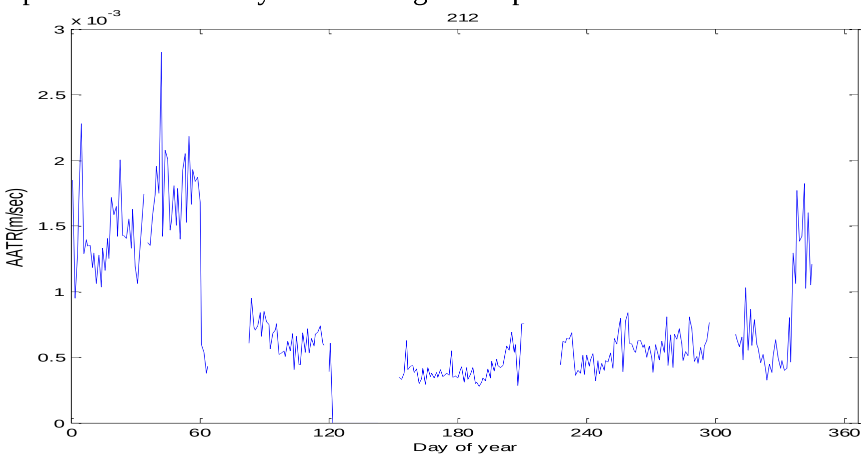

Figure 3 (b): Daily mean RMS AATR values for all available days of year 2004 at New Delhi (28.56° N, 77.22° E)

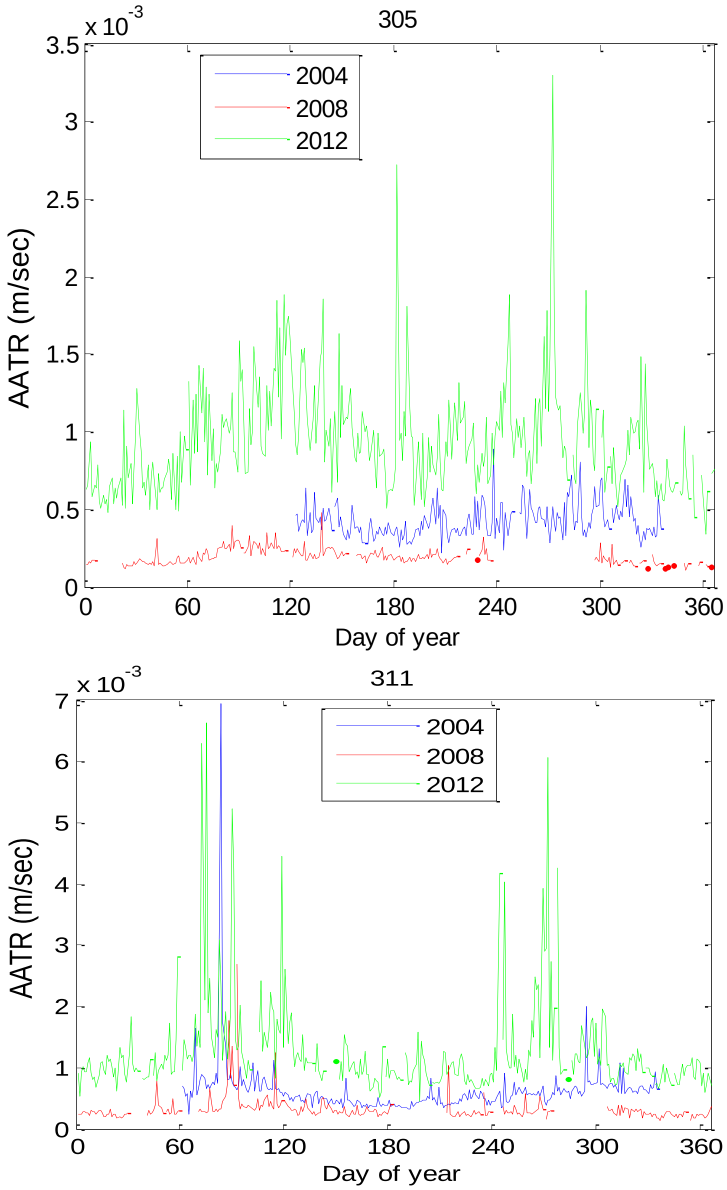

Figure 4: Comparison of daily mean AATR for the years-2004, 2008, 2012 for the low mid latitude station- Shimla (top, 31.08° N, 77.06° E) and low latitude station- Aizwal (bottom, 23.84° N, 92.67° E).

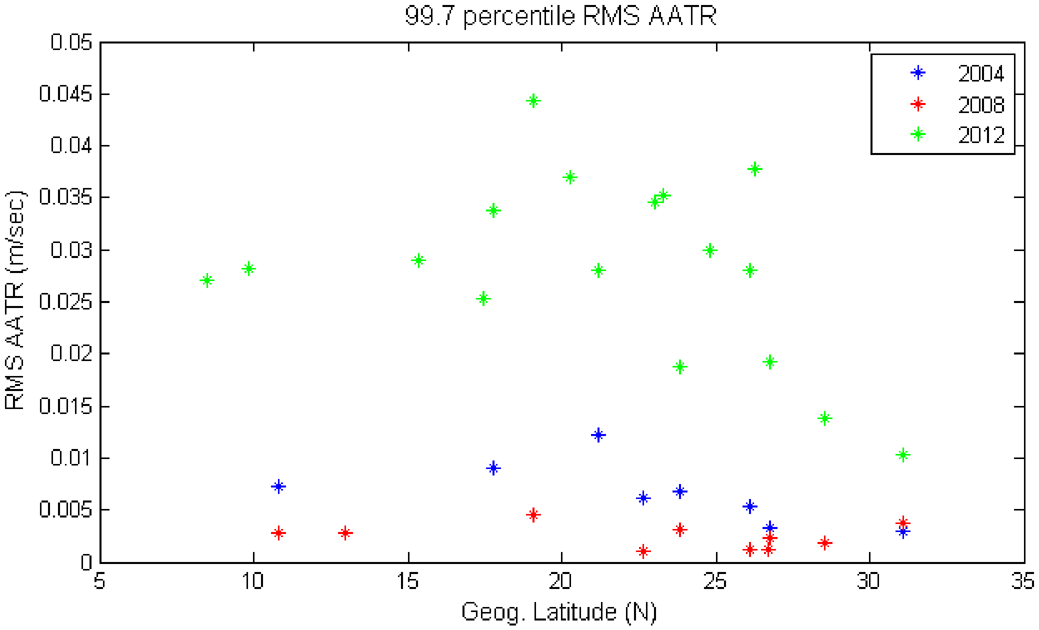

Figure 5: Variation of 99.7th percentile of AATR with geographic latitude for the years-2004, 2008 and 2012.

4. Action required by the meeting

4.1 The meeting is invited to:

a) accept the testing and verification process adopted by India for evaluation of results from different AATR tools;

b) evaluate the results for any possible improvement in the tools;

c) evaluate the advantages of AATR in the regional Ionospheric analysis; and

d) discuss any relevant matters as appropriate.

— — — — — — — — — — — — —